(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 May 2001 (25.05.2001)

PCT

(10) International Publication Number
WO 01/36772 A1

(51) International Patent Classification⁷: E05F 15/20, H02P 1/22

(21) International Application Number: PCT/US00/21510

(22) International Filing Date: 4 August 2000 (04.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/443,540 19 November 1999 (19.11.1999) US

(71) Applicant: PROSPECTS, CORP. [US/US]; Suite 406, 40,000 Grand River Avenue, Novi, MI 48375 (US).

(72) Inventors: O'CONNOR, Christopher, J.; 37921 Meadowhill Drive, Northville, MI 48167 (US). HAWLEY, Stephen, A.; 2 Hill Road, Bedford, MA 01730 (US). CHAPDELAINE, Eugene, R.; 27 Sandstone Drive, Bedford, NH 03110 (US).

(74) Agents: MORIARTY, Gordon, R. et al.; Weingarten, Schurgin, Gagnebin & Hayes LLP, Ten Post Office Square, Boston, MA 02109 (US).

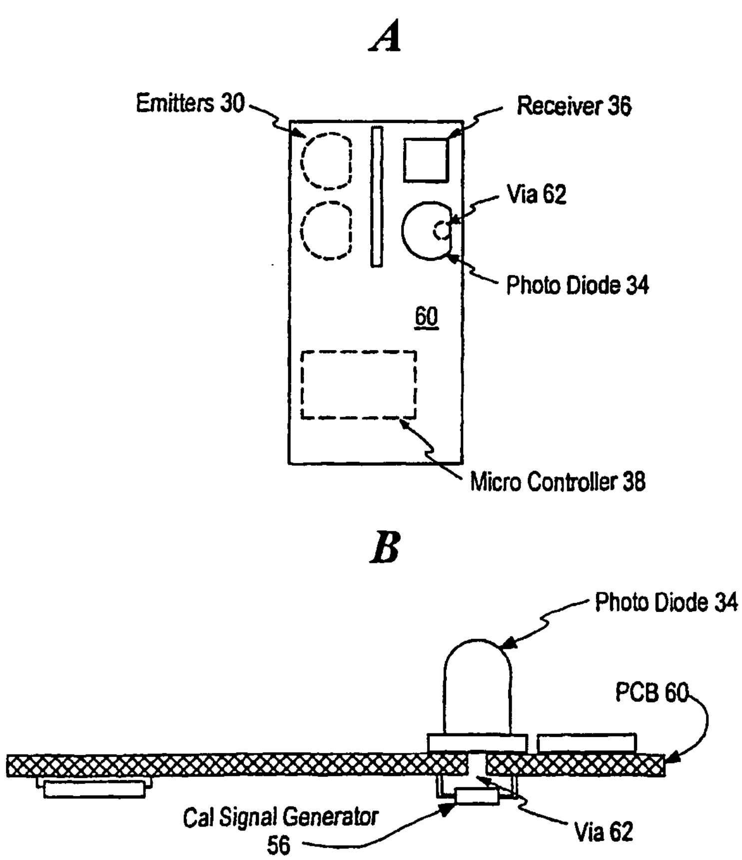
(81) Designated States *(national)*: CA, JP, KR, MX.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

**Published:**
— *With international search report.*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: INTEGRATED OBSTACLE DETECTION SYSTEM




(57) Abstract: A hybrid obstacle detection system for a power driven closure (12) including a non-contact obstacle detection system (14) and a contact-based obstacle detection system (100). The hybrid system combines the beneficial aspects of contact and non-contact systems while avoiding the deficiencies characteristic of the constituent systems when employed alone. In the non-contact system, the closure itself may interfere with and degrade performance. In the contact-based system, physical contact with an obstacle is required before the obstacle can be detected and corrective action can be taken. Inputs from both the contact-based system and the non-contact system may be utilized over the entire closure travel path, or may be invoked only within a specific portion of the closure travel path. Either or both of the constituent systems may be used to ascertain the location of the closure. A central controller (202) may be used for coordinating the inputs from the two systems, or a controller associated with one of these systems may be adapted for this purpose. If the central controller is employed, it may be a controller dedicated to this function, or one which is already utilized in the environment of the aperture for another purpose.

WO 01/36772 A1

# TITLE OF THE INVENTION

# INTEGRATED OBSTACLE DETECTION SYSTEM

## CROSS REFERENCE TO RELATED APPLICATIONS

N/A

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

N/A

## BACKGROUND OF THE INVENTION

The development of small, powerful motors over recent decades and the desire for added convenience have led to an increase in the number of settings in which a closure is driven automatically across an aperture, rather than requiring manual manipulation. For instance, power windows for motor vehicles are commonplace today. Similarly, closures such as hatches or doors are known to be driven by such motors.

As a further advancement, these power-driven closures have recently been provided with control circuitry which recognizes a particular command or set of commands which result in the automatic operation of the closure, without the further input of an operator. In the vehicle setting, this is recognized as the case of express-close or one-touch close power windows. By briefly activating the window control, an operator can cause the power window to travel from any open position to a fully closed position.

With the convenience of such power-driven closures has come a risk of entrapment, particularly for children and animals. In the vehicle window or sunroof setting, several distinct approaches have been taken towards detecting the presence of an obstacle, such as a child, an animal, or an inanimate object, and consequently overriding an express close command to avoid trapping the obstacle by the closure.

One such approach involves the monitoring of the current supplied to the closure actuating motor. Typically, the motor opens and closes the closure in the aperture by rotating a drive shaft or armature. The elements which actually move the closure are typically in mechanical communication with the drive shaft through one or more gears. When the motor is activated, the motor current fluctuates both as a result of variations in forces opposing the motion as well as in a periodic fashion as a result of the rotation of magnetic elements inside the motor. By monitoring the fluctuation of the motor current with motor rotation, a gauge of motor operation and closure travel may be established. Thus, a known number of pulses that can be derived from the periodic component in the motor drive current may be equated to closure travel from a fully open position to a fully closed position. This is commonly referred to as motor current ripple counting.

A monitoring circuit associated with the closure controls may be provided with a timer and a pre-established threshold for a normal travel time for an associated closure from a fully open to a fully closed state. By combining the positional information gained by monitoring the motor drive current with the time threshold, it may be established whether a powered closure reached a fully closed state within an acceptable time period. Additionally, if the

ripple frequency is monitored, an estimate of the velocity of motion may be derived. If the closure does not reach a fully closed state either in an acceptable time period or the velocity decreases unexpectedly, then obstacle entrapment may be inferred and a number of actions may be taken, including the automatic reversal of the closure. An obvious drawback to this form of obstacle detection and entrapment avoidance is the fact that the obstacle must actually be entrapped and thereby squeezed in order to be successfully detected, before corrective action is taken such as reversing the direction of travel of the closure. This is referred to as a "contact" obstacle detection system.

An alternative approach to obstacle detection involves the use of a projected field or beam of electromagnetic energy directed across the aperture or a portion thereof or proximate thereto. Under normal circumstances, a pre-established level of emitted energy will be detected by an associated receiver. If an obstacle is present within the field of energy adjacent or within the aperture, the emitted field will be altered; the receiver circuitry detects a variation in the amount of detected energy and, depending upon the degree of the variation, invokes corrective action such as the reversal of the closure. This system may be referred to as a "non-contact" obstacle detection system.

This system may also experience certain deficiencies, depending in part upon the geometry of the aperture, the environment and the disposition of the energy emitter and detector with respect to the aperture. For instance, one or more "blind spots" may be present as the closure is moved towards a closed position, resulting from interference by the closure or the aperture structure. As the powered

closure nears the "closed" position within the aperture, it enters what may be referred to as a "pinch zone," a region in which a small obstacle such as a child's hand may be present but which because of its size may be difficult to detect through the monitoring of the power level of reflected energy.

In summary, both of the existing approaches to obstacle detection within an aperture having a power-driven closure, when used alone, may suffer from the aforementioned limitations which could result in injury to an obstacle present in the path of the closure.

## BRIEF SUMMARY OF THE INVENTION

The present invention relates to an obstacle detection system for a power driven closure, the system combining the beneficial aspects of the contact and non-contact systems previously discussed while avoiding the deficiencies characteristic of these systems when employed alone.

As noted, a non-contact system may perform adequately over a majority of the range of motion for a respective power-driven closure. However, as the closure reaches a terminal portion of its travel path within the aperture, the closure itself may interfere with and degrade the performance of the system to a degree that smaller objects may not be detected. Entrapment may then result.

To ensure the ability to detect objects in this region, the presently disclosed invention combines a contact-based system with a non-contact system. The combination may be utilized over the entire range of travel of the closure, or may be invoked only within the pinch zone, however that region is defined. If the input from a contact-based system is employed only within the pinch zone, a number of factors

may be utilized in determining the actual position of the closure. For instance, a ripple count technique may be utilized, or the non-contact system itself may have a characteristic output once the closure is at a particular position. A timer or clock source may also be utilized as an input for the purpose of establishing the rate of movement for the closure.

Alternatively, one or more switches may be utilized, including a mechanical switch disposed in conjunction with the closure. An optical switch including a feature disposed in conjunction with the closure, such as a tab for interrupting a beam of optical energy between an emitter and a detector, may also be used.

A central controller may be used for coordinating the inputs from the two systems, or a controller associated with one of these systems may be adapted for this purpose. If a central controller is employed, it may be a controller dedicated to this function, or one which is already utilized in the environment of the aperture for another purpose.

The presently disclosed system may also be adapted to respond to a broad range of inputs from the two systems and to provide an appropriate response thereto. If the non-contact system does not report uncharacteristic performance during the terminal portion of closure travel, but the contact-based system indicates that the closure is travelling slower than expected, various inferences may be made. It may be indicated that an obstacle is present. Alternatively, it may be determined that there exists a general degradation in the closure motor, a temperature-related response by the closure motor, or dirt or ice buildup on the closure. Depending on the environment in which the closure is expected to be located, various

combinations of inputs may result in the determination that an obstacle is present.

Conversely, if the non-contact system detects returned energy levels outside predetermined norms, normally an indication of the presence of an obstacle, but the contact-based system does not register aberrant performance of the closure, the combined system may declare the absence of an obstacle. The controller may then utilize the measurements of the non-contact system to adjust the non-contact system parameters. This adjustment may take a variety of forms, including averaging returns over a number of cycles and adjusting threshold values based on the averaged returns, such as by an certain percentage of the average returned energy in the absence of an obstacle. Further, the average returned energy under these circumstances may be used as a new center-point for a range of acceptable energy values.

A further advantage of combining these systems into a new hybrid system is a failsafe mode of operation. If the non-contact system fails due to an inoperative or obstructed emitter or receiver, the contact system may be relied upon solely by the joint controller. Conversely, if the contact-based system loses the ability to track closure motion or location, the non-contact system may be relied upon by the joint controller. In conjunction with these modes of operation, a warning may be provided to an operator of this impaired state in the hybrid system and/or a log of the event may be recorded in memory associated with the joint controller for subsequent reference by maintenance personnel.

Yet another advantage afforded by the presently disclosed hybrid system is the ability to provide a reliable indication of the completion of an express close operation.

With a non-contact system, such an indication may be inferred, but with a lower degree of confidence.

Thus, a more accurate, flexible system for obstacle detection is enabled through the combination and adaptation of contact and non-contact systems.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Fig. 1 is a block diagram of a non-contact aperture monitoring system according to the present disclosure;

Figs. 2A, 2B and 2C are illustrations of the placement of aperture monitoring systems, such as of Fig. 1, in a vehicle for use with vehicle windows;

Fig. 3 is a top view of the systems of Fig. 2A;

Fig. 4 is a further block diagram of the monitoring system of Fig. 1;

Fig. 5 is a perspective view of the interior of a vehicle door illustrating surfaces which reflect radiation emitted by the aperture monitoring system of Fig. 1;

Fig. 6A is a plan view of a circuit board for mounting elements of the monitoring system of Fig. 1;

Fig. 6B is an elevation view of the circuit board of Fig. 6A;

Fig. 7 is a block diagram of a contact-based obstacle detection system according to the present disclosure;

Fig. 8 is a block diagram of various elements comprising the contact-based obstacle detection system of Fig. 7; and

Fig. 9 is a block diagram of a hybrid obstacle detection system according to the present disclosure.

## DETAILED DESCRIPTION OF THE INVENTION

A non-contact system for the detection of one or more obstacles within an aperture includes an emitter for the creation of a field of energy within and/or proximate to the aperture. A receiver is provided to detect that portion of the field which is reflected back. Alternatively, the receiver may be positioned to directly receive the emitted energy. When an obstacle enters the energy field, it alters the amount of energy which is detected by the receiver, either by altering the amount of reflected energy or by diminishing the amount of energy transmitted to the receiver. Depending upon the magnitude of this alteration, an obstacle detection indication may be generated, enabling the implementation of corrective action.

In industrial settings, an automatic door benefits from the use of a system which monitors whether the door would be obstructed if closed. Likewise, in automotive applications, an appropriately adapted monitoring system finds utility in preventing entrapment within power windows, sunroofs, doors, or other aperture closures. Such monitoring systems may include a non-contact system comprising an emitter for generating an appropriately patterned radiation field adjacent or within the aperture. Surfaces close to the aperture and within the field of the radiation pattern reflect the radiation. A receiver is positioned to receive radiation which is reflected from those surfaces. Normally, without any foreign objects interjected into the radiation field, the energy level of the reflected radiation does not exceed an alarm threshold stored in a memory element in conjunction with the receiver.

However, if a foreign object such as a human or animal limb is close to or within the aperture, the reflected radiation will be altered to a degree that the reflected radiation does exceed the alarm threshold. In one embodiment, the level of reflected radiation is decreased as a result of the foreign object absorbing part of the radiation that would otherwise be reflected back to the receiver, blocking part of the reflected radiation from reaching the receiver, or both. In another embodiment, the level of reflected radiation is increased as a result of emitted radiation reflected off the foreign object and back to the receiver rather than being absorbed by the aperture environment surface(s).

With respect to Figs. 1 - 6B, one embodiment of a non-contact system is illustrated and described. As shown in Fig. 1, a detector, comprising a receiver and a controller, may include an optical detector, an infrared detector, an ultrasound detector, or similar devices. The receiver may be either integral with or in communication with the controller, which is alternatively referred to as a processor. The receiver output is indicative of the strength of the received, reflected radiation. For example, the receiver may produce plural pulses having durations related to the intensity of the energy received by the detector. The detector may then deliver a detection signal when the duration of one pulse exceeds a predetermined value, referred to as a threshold. Alternatively, the detector may produce the detection signal when the duration of each of a predetermined number of consecutive pulses exceeds the threshold.

The threshold may be related to the duration of a pulse when no obstruction is present or the average duration of

pulses produced when no obstruction is present and a closure such as a window or door moves from an open position to a closed position. The threshold may include a correction factor that accounts for variations in the duration of pulses produced when no obstruction is present, and may vary based upon the position of the closure. The threshold, or some other value indicative of an obstruction-free opening, may be stored during an initialization procedure. The threshold may be a single value, whereby an alarm condition is recognized if a pulse duration value is either above or below the threshold, depending upon the embodiment. Alternatively, the threshold may be defined by a range of acceptable values, whereby an alarm condition is recognized if the pulse duration value is only above this range, only below this range, or either above or below the range.

Alternatively, the detector may provide some other output signal representative of the received radiation strength, such as an analog signal whose voltage varies with the level of the received radiation.

The detector and emitter may be contained in an integral unit, which may be a compact unit in which the detector and the emitter share a common lens. The emitter may include a light emitting diode or a laser device.

Automatic closing or opening of the closure within the aperture may be initiated by a rain sensor, a temperature sensor, a motion sensor, a light sensor, or by manual activation of a switch. Thus, a system according to the present disclosure may be provided with a signal commanding the opening or closing of an aperture, this signal coming from one of many possible sources. The illustrated non-contact monitoring system may be activated after receipt of this commanding signal and before operation of the powered

closure, though it can also be utilized to determine aperture environment status at any other time.

With respect to Figs. 2A, 2B and 2C, a non-contact aperture monitoring system is illustrated in the form of a vehicle window monitoring system. This system includes a front emitter/receiver unit 14 disposed in a front door 10 and positioned to produce an energy curtain 16 in a region to be traversed by a front window. Also provided is a rear emitter/receiver unit 14A in a rear door 10A, positioned to produce a second energy curtain 16A. An opposite side of the vehicle would typically be provided with like monitoring systems for the respective windows.

The emitter/receiver units 14, 14A include emitters that produce the energy curtains 16, 16A and receivers that detect any portion of the respective energy curtain that is reflected back to the emitter/receiver units 14, 14A from the window frame 20, 20A. As noted elsewhere and depending upon the monitoring system embodiment, an obstacle interjected into the radiation field either increases or decreases this reflected portion of the radiation curtain. The emitter/receiver unit may also be provided to enable synchronous detection.

The front emitter/receiver unit 14 is positioned at the lower front corner of the window aperture. This ensures that the energy curtain 16 covers a significant portion of the window aperture, a portion in which an obstruction could be caught between the window and the surrounding window frame. The rear emitter/receiver unit 14A may also be positioned at the lower front corner of the window, though it may be preferable, depending upon the size, shape and travel path of the window, to locate the emitter/receiver unit 14A at a lower-center or upper-forward window position

to increase the likelihood that an obstacle will be detected, such as shown in Figs. 2B and 2C.

With respect to Fig. 3, the two emitter/receiver units 14, 14A of Fig. 2A are positioned so that horizontal angles $\beta_1$, $\beta_2$ of the energy curtains 16, 16A are roughly centered in the window frame 20, 20A of the door 10, 10A. This ensures that, even if an emitter/receiver unit 14, 14A is mis-aligned due to vibration, repeated door closure, or other reason, the energy curtains 16, 16A will still be capable of detecting obstructions in the planes defined by the respective windows. Installation concerns arising from aligning discrete emitter and receiver units are also addressed by packaging the emitter and receiver in the same physical package. Common packaging also minimizes the opportunity for misalignment between the emitter and receiver due to environmental vibration or shock.

The installations illustrated for the vehicle window embodiments in Figs. 2A, 2B, 2C and 3 may be instructive in envisioning installations proximate sunroofs, power doors or other apertures having power or automatic closures. What is required is an emitter/receiver unit positioned relative to the aperture such that a radiation field is capable of being emitted adjacent or within the respective aperture, or both; a predictable radiation return is generated in the absence of a foreign object near or within the aperture.

A controller associated with the emitter/receiver unit operates the aperture monitoring system. Typically, the controller does not activate the monitoring system until the controller has received a close request signal. Automatic close requests can be generated by the controller itself in response to input from various environmental sensors such as

a rain sensor or a temperature sensor. An automatic close request can also be generated by a vehicle operator or passenger, and is typically identified by the controller as the activation of a window control switch for more than a certain time period, e.g. 3/10 second.

If the close request is an automatic close request, the controller activates the appropriate emitter, then the characteristics of the receiver output pulse are analyzed. In an embodiment where the output pulse width is varied according to the received radiation strength, the presence of an obstruction adjacent or within the aperture is reflected in a variance of the receiver output pulse widths from a predicted norm. Thus, the controller detects obstructions by comparing the output pulse width t to T′, an initialization value related to the length of a detection pulse produced by the receiver when an aperture environment is free from obstructions. T′ is generated in an initialization procedure during installation of the system. The emitter is activated and the detection signal is monitored while the aperture is closed under obstruction-free conditions. T, the average value of the output pulse width while the window is being closed, is determined from the detection signal. T′ is thus generated as:

$$T' = T + 2\sqrt{T}$$

where the square-root term allows some deviation in the value of an acceptable t and thereby accounts for deviation that could be caused by variations in system power.

The controller receives inputs from various system sensors, such as a rain sensor, temperature sensor, light sensor and the aperture monitoring system, and provides control signals to window motors, a sunroof motor, or an

automatic door motor, depending upon the specific application. The controller can also interface the aperture monitoring system to an alarm unit which may produce audible or visual alarms, and which may prevent vehicle operation. The alarm unit may also transmit an alarm or beacon signal, such as an RF signal at a specified frequency.

With respect to Fig. 4, a block diagram of a non-contact aperture monitoring system is illustrated. This embodiment includes one or more radiation plane light emitting diodes (LEDs) (labeled here as Emitters) 30, a photo IC 32 including a photodiode 34 for detecting reflected radiation, and a controller 38. The radiation plane LEDs 30 are also referred to as radiation LEDs, radiation plane LEDs, IR LEDs, drive LEDs, measurement LEDs, or collectively as a measurement emitter. While other operating frequencies are possible, the radiation plane LEDs preferably emit at 38KHz with a 90% duty cycle to avoid interference from other radiation sources including remote door controllers, solar emission, etc. A 38KHz switch 40 enables emission at this frequency. The greater the energy level of the radiation received at the photodiode 34 and the receiver 36, the longer a pulse width for each of plural consecutive pulses in an output stream comprising a receiver output signal. Experimentally, it has been found that a receiver output pulse width of 30ms to 40ms in the absence of an obstacle is optimal for the presently disclosed system, though other time periods are employable. A threshold value for pulse length is established and stored in memory associated with the controller. For a receiver pulse width of 30ms to 40ms, a suitable threshold is +/- 3ms, though other threshold values may be employed according to the needs of the particular monitoring system embodiment.

The controller compares detected receiver output pulse widths to the stored threshold value. If the output signal pulse width equals or exceeds the threshold, or simply exceeds, depending upon the embodiment, obstacle detection may be established.

Other elements making up the aperture monitoring system include a read-only memory element (such as the illustrated EEPROM 44), a voltage regulator 46, a temperature sensing element 50, first and second digital potentiometers 52A, 52B, an analog switch 54, and a calibration signal generator 56. The EEPROM 44 is provided as storage for controller 38 data including threshold values for comparison against the receiver 36 output. The voltage regulator 46 provides variable power to the calibration signal generator 56 and the radiation plane LEDs 30. The temperature sensor 50 provides an indication to the controller 38 of the operating temperature for the monitoring system. The digital potentiometers 52A, 52B are used to adjust the receiver gain and the output level of the calibration and radiation plane LEDs 56, 30, based in part on the ambient temperature. The analog switch 54 represents a gain control element for the receiver 36.

A calibration signal generator 56, which may be a light emitting diode (LED), is illustrated in Fig. 4. This LED 56 is preferably disposed on a single circuit board 60, as shown in Figs. 6A and 6B, along with the other system elements. In order to make the monitoring system as unobtrusive as possible in a vehicle application, it is preferred to densely pack the elements on the circuit board 60, the latter having plural conductive and insulating layers. This enables the circuit board 60 to have circuitry on both sides, as shown in Fig. 6B. In one embodiment, the

receiver and photodiode 34 are disposed on a side of the circuit board 60 opposite the bulk of the remaining circuitry, including the calibration LED 56. This facilitates electromagnetic isolation of the receiver, leading to improved system performance.

The reference LED 56 is separately controlled with respect to the IR LEDs 30. A small aperture such as a plated via 62 through the printed circuit board is provided between the calibration LED 56 (also referred to as the reference LED) and the photodiode 34 in the receiver portion of the monitoring system. The calibration LED 56 is preferably chosen with temperature response characteristics similar to those of the IR LEDs 30; it is possible to account for the temperature response of the IR LEDs 30 through the normal calibration process prior to each use of the monitoring system.

A further advantage of employing a calibration LED 56 and IR LEDs 30 having a common temperature response curve which is inverse to that of the receiver 36 is that at least a portion of the temperature-dependent variation in receiver performance is automatically offset by the decrease in LED efficiency with increased temperature. This results in a reduction in the overall loop gain necessary to keep the monitoring system at a stable operating point.

Experimental results indicate that a 30ms to 40ms output pulse is the optimum value for output pulse widths from the receiver, though higher or lower periods are used in alternative embodiments. It is therefore desired to have the receiver output be in this range in the absence of an obstacle in or proximate the aperture being monitored. This is achieved by activating the calibration LED 56, whose radiation impinges upon the photodiode 34 of the photo IC 32

in the receiver section of the system, then adjusting the receiver gain by the controller 38 to produce a desired output pulse width. The calibration LED 56 drive current is used to determine the proper drive current for the IR LEDs 30, which should then produce the same receiver output in the absence of obstacles. This is because a previously performed calibration step correlates the drive current for the calibration LED 56 with the drive current for the IR LEDs 30 such that both produce the same output from the monitoring system receiver 36, the calibration LED 56 by emitting radiation through the via 62 in the circuit board 60, and the IR LEDs 30 through emitting radiation adjacent and/or within the respective aperture and causing a given amount of radiation to be reflected back to the photodiode 34. In one embodiment, the calibration LED 56 is activated for this purpose for approximately 10mS.

In contrast to the foregoing non-contact system, a contact-based system detects a change in the operating characteristics of the closure, such as a window, during a close operation. Such systems include time-based systems and motor characteristic-based systems.

With reference to Fig. 7, a time-based obstacle detection system 100 relies upon a predetermined acceptable range of times for a closure to reach a fully closed position within an aperture, or to reach some intermediate position in the aperture. A controller 102, such as a programmable microprocessor, is in communication with a source of timing data such as a local oscillator 104. The local oscillator may be replaced by an external timing signal from another system. Also associated with the controller is a memory 106 which retains data pertaining to the length of time an obstruction-free closure 108 would

take to move a given distance, or to move from one position in the aperture 110 to another. Alternatively, a range of acceptable times is provided in the memory. The same memory element may also be used to store the closure position relative to the aperture at any given instant; this information may be used to recover window position once power is restored following a power interrupt. The controller would simply write the derived position information to the memory on a periodic basis. This feature is particularly useful if the closure was in a partially open state at the time of the power interrupt.

The controller 102 is also in communication with a motor 112. The motor 112 is in mechanical communication with the closure 108 through one of a variety of mechanical arrangements as well known to one skilled in the art. Typically, a linear relationship exists between the number of motor drive shaft rotations and the linear displacement of the associated closure. Likewise, there is typically a linear relationship between the motor rotational rate and the rate of motion of the closure. Given these relationships, the controller 102 can infer the closure 108 position within the aperture 110 in a variety of ways once a start position (such as a fully retracted position) is known. The controller 102 can further establish whether the closure is in the right location in the aperture 110 at the right time, or alternatively if the closure 108 is travelling at the correct range of speeds. Further still, another embodiment of such a system may confirm whether the closure motor speed has the proper rate of change as the closure is moved.

In order to establish whether the closure 108 is in certain critical locations in the aperture 110 at a given

time, some means 114 must be provided in association with the closure to establish relative position. These means 112 may include: an optical sensor operating in conjunction with some form of encoded symbology disposed on the closure 108 or in conjunction with a tab for interrupting a light beam emitted and detected by the optical sensor; a sensor responsive to a plurality of elements disposed in conjunction with the closure, each such element having a unique characteristic such that closure position may be inferred by determining where the series of elements are located relative to the sensor; a plurality of sensors disposed proximate the aperture and the closure path of travel for detecting one or more elements disposed in conjunction with the closure; or other such arrangements. The sensor may be optical, magnetic, or mechanical, with the appropriate type of cooperating element being disposed in association with the closure. Alternatively, a mechanical sensor or series of sensors may be employed in the aperture 110 which are capable of detecting the closure 108 without the need for additional signaling elements on the closure 108 itself. Further, sensing elements may be disposed on the closure, with the cooperating elements to be sensed disposed in conjunction with the aperture 110, adjacent the travel path of the closure 108. In the latter case, the cooperating elements may be active, such as magnets for a magnetic sensor, or passive, such as indicia to be scanned by an optical scanner.

Closure position information is employed by the controller 102 in order to determine if the closure 108 is in the correct position, or range of positions, at the right time, or range of times. These ranges may be established through empirical analysis of closure function over a range

of operating environments in which the closure system may be disposed.

A further contact-based system may avoid the need for a discrete sensor and detectable elements by monitoring the motor 112 which drives the closure 108 in the aperture 110. In this embodiment, some characteristic of the motor 112 is monitored in order to gauge the operation of the closure 108. The motor 112 current typically exhibits periodic fluctuations in conjunction with the rotation of the motor drive shaft. In one embodiment, the motor drive current may be monitored by inserting a resistor 120 in series with the motor supply, then sending the detected potential through an AC amplifier 122 with a specific predetermined frequency response. The amplifier 122 output is converted into a square wave by a converter circuit 124 as known to one skilled in the art. A counter 126 is then used to count the number of pulses in the motor supply current. This count, also referred to as a ripple count, is used as a measure of the distance the closure 108 has traveled. The frequency of occurrence of these pulses is used as a measure of the motor speed.

One potential drawback with a ripple count circuit is the potential need to adapt the controller 102 if the motor 112 is replaced, as each motor has its own characteristic periodic fluctuation. Thus, one motor 112 may have periodic signals from which a square wave or ripple may be extracted, while a replacement motor 112 may have a more complex periodic waveform. To address this situation, a further embodiment of a contact-based system employs metrics derived more generally from the periodic nature of the motor current, without requiring that the motor signal be converted to a square wave. For instance, if the spectral

density function associated with the motor current is derived then the mean frequency can be monitored as a measure of closure speed. In a similar fashion the autocorrelation function associated with the motor current may be derived. Alternatively, in a simple implementation, the frequency content may be assessed by monitoring the energy passed by one or more frequency selective filters.

The measurement of the impeding force experienced by the closure can be detected as an unexpected decrease in closure velocity as revealed by a corresponding decrease in the required components. For instance, a measured rate which deviates from an expected rate by a small percentage may be interpreted as an accumulation of ice or dirt on the closure, whereas a larger deviation may be interpreted as the detection of an obstacle. The establishment of acceptable ranges and the rules which define the interpretation of the measured data are achieved based on the expected environment in which the aperture and closure are to be located and the empirical response by the closure system to a variety of test conditions, including the insertion of test obstacles.

In order to supplement the ability of a contact-based system to detect an obstacle, or to provide an indication that an obstacle is more likely than not, a measure of the motor drive current may be employed through the use of a current detection circuit 130. The specific implementation of this circuit 130 may be as known to one skilled in the art. Thus, if the pulse counter 126 indicates that the closure 108 reached a certain position in the aperture at a time outside an acceptable range, but the monitored motor current was within a normal range during the closure travel, it may be inferred that the motor itself has degraded and is

now unable to raise the closure in the target time range. In a further embodiment of a contact-based system as disclosed, the range of acceptable times is shifted in order to compensate for a slowing trend in motor function. Also to be considered in a system which updates the acceptable ranges are a number of past measurements as stored in memory 106 associated with the controller 106. Thus, if a given number of previous measurements have exhibited a similar shift in performance, this may be cause for redefining the acceptable range of counter values or closure travel rates.

The more factors characterizing closure behavior that are considered, the better the opportunity for accurately discriminating the presence of an obstacle from aberrant behavior of the closure system absent an obstacle. Therefore, the use of detected DC motor current in conjunction with the measurements taken with respect to the distance traveled by the closure or the rate at which the closure traveled for a given period yields a more reliable interpretation of closure function, when only a contact-based system is used.

However, a contact-based system must still rely upon the actual entrapment of an obstacle in order to initiate corrective procedures. As previously acknowledged, it is preferable to provide a system which enables the detection of obstacles without the need for entrapment first. Yet, non-contact systems may suffer from degraded sensitivity in the terminal portion of the closure travel path within the aperture, potentially depending upon the location of the sensor system in relation to the aperture and closure and upon the physical configuration of the aperture and closure themselves. Non-contact systems also may not provide a high

degree of confidence in the belief that a closure has reached a terminal position within the aperture.

Thus, a more accurate obstacle detection system is realized through the use of both contact and non-contact obstacle detection systems. Such a hybrid system is illustrated in block diagram form in Fig. 9, where the non-contact system may include the emitter/detector module 14 of Figs. 1-6B and the contact-based system may include one of the detector arrangements described in conjunction with the system 100 of Fig. 7. In an alternative embodiment, the non-contact system includes an ultrasound, or ultrasonic, emitter/detector, as known in the prior art. The ultrasound emitter/detector module may be located at the same or a similar position proximate the respective aperture as that for the IR emitter/detector module. The non-contact system avoids entrapment of an obstacle in the detection process, while the contact-based system provides an accurate indication of closure relative position as well as supplemental obstacle detection at closure positions for which the non-contact system sensitivity is less than optimal.

The controller employed in the hybrid system of Fig. 9 may be the controller 102 used in conjunction with the contact-based system of Fig. 7, the controller 38 of the non-contact system of Fig. 3, a dedicated controller 202 working in conjunction with the first two controllers 38, 102, or a processing element already found in the aperture environment and adapted for use in controlling such a hybrid system. For instance, in a vehicle aperture embodiment, an electronics module which communicates over a vehicle communications bus may be adapted for this purpose. Communications between the elements of the presently

disclosed hybrid system, including the one or more controllers, is preferably through standard communications pathways or buses. Such pathways may be electrically conductive or optical.

The degree to which the sensitivity of a non-contact system varies is most likely dependent on closure position and/or obstacle position within the aperture. These factors can then be used to define the point at which factors from a contact-based system are considered or are emphasized in making a determination of whether an obstacle is present.

For instance, testing with a variety of obstacles may indicate that a non-contact system such as one employing an IR emitter and associated detector is extremely sensitive over the lower 75% of an aperture. Thus, over this portion of the aperture, the controller 102 may rely solely on the output from the detector portion of the non-contact system, such as that shown in Figs. 1-6B. An indication of closure position may be provided as an input from the contact-based system 100. Additionally, closure position may be inferred as a result of detection by the non-contact system 14. For instance, a characteristic change may be observable in the non-contact system output when the closure reaches a certain position within the aperture.

As the closure 12 is driven into the final 25% of its travel path within the aperture 20 in this example, input from the contact-based system may be utilized in conjunction with the non-contact system information in determining whether an obstacle is present. In this example, the final 25% of the travel path may be defined as the "pinch zone." Thus, as in Fig. 9, a common controller or processing element 200 receives inputs from both systems and, depending

upon closure position, relies on one or both for obstacle detection.

Assume the aperture has nearly reached the top of its travel path. The non-contact system receiver output is within the normal range. However, the contact-based system indicates that the closure motor is rotating at a rate below a previously established minimum threshold. The controller may be programmed to interpret this data in a variety of ways. If the deviation in motor speed is slight, prior empirical analysis may suggest that the closure motor is exhibiting temperature related effects, or that the closure itself may be fouled with ice or debris. A temperature indicating device may be utilized as a further input to confirm or rule out such an option. If the deviation in motor speed is significant, it may be established that an obstacle is present, one which was not detected by the non-contact system. In the latter case, appropriate action is invoked to free the perceived obstacle, including the reversal of closure travel direction and/or the activation of an alarm.

Alternatively, the motor driving the closure may be slowed subsequent to an initial, preliminary indication from the non-contact system that an obstacle may be present. In this embodiment, different tolerances for the sensor thresholds (contact and/or non-contact) may be applied in order to make a more accurate determination of whether an obstacle is indeed present. If so, the corrective action referred to above is invoked.

Another advantage of employing dual systems for obstacle detection is evident when the non-contact system receives returned energy which is beyond a threshold level (either above or below, depending upon the specific

embodiment of the non-contact system). By referencing the contact-based system, it is possible to determine if the non-contact system's result is indeed indicative of an obstacle or of a change in the performance of the non-contact system which must be accounted for.

If it is established through the contact-based system that no obstacle is present, the combined system can be provided with the capacity to dynamically adjust to variations in the background-reflected radiation. This can be achieved in a number of ways. The detected energy level may be averaged with the difference between each of a selected number of previously detected energy levels and the threshold, as stored in memory associated with the system. The result of this averaging process is utilized in defining an offset for the non-contact system for future cycles. For instance, an offset can be defined for the emitter, or for the receiver gain. This offset can cause an adjustment in the difference between the threshold value and the receiver output by a percentage of the averaged variations. The number of samples from the previous measurements to be averaged can be varied depending upon the rate at which background-reflected radiation is expected to change as a result of predicted surface degradation, or based upon an empirical analysis by the system of the rate of change of background-reflected radiation. Alternatively, the difference between the current receiver output and the threshold may be used without previous measurements in defining an appropriate offset. Still further, a desired number of discontinuous prior measurements is utilized in an averaging process.

In a further embodiment of the present hybrid system, the controller 202 may have associated with it a memory 204

for storing threshold values for both the non-contact and contact systems, for storing the appropriate actions to be taken depending upon which thresholds are achieved, and for storing empirical data reflective of previous measurements from the non-contact and contact systems. Thus, if the non-contact system fails to register an object and the contact-based system registers a motor rotation rate slightly below a pre-established threshold, the controller may reference the most recently stored performance data for the closure to determine if a trend towards slower motor rotation rate can be established. If so, the relevant thresholds for the motor rotation rate can be adjusted accordingly for future reference.

In a further embodiment, the memory element may be used to store an acceptable speed pattern as a function of closure position should this not be a constant value. This might be necessary if for example extra force is required to bring the closure to a fully closed position where a gasket seal is required.

If the non-contact system has once again failed to register an obstacle, but the contact-based system has exhibited a significantly slower motor rotation rate or a closure position which is short of the fully closed position within the aperture, an obstacle detection may be recognized, and the thresholds for the non-contact system may be adjusted incrementally in order to increase the sensitivity of the non-contact system.

Alternatively, the contact-based system may be considered in conjunction with the non-contact system over the entire range of closure travel. The controller may then employ multiple factors in establishing the presence of an obstacle. These factors may include the level of reflected

energy or the time at which energy was received relative to the time it was emitted, both factors coming from the non-contact system. Additionally, the controller may employ one or more of the motor rotation speed (and thus the closure travel rate), the closure absolute position, and the rate of change in the closure travel rate, all coming from the contact-based system.

Thus, the controller 202 according to the present disclosure operates in conjunction with a knowledge base adapted to classify a variety of contact and non-contact system inputs for the purpose of identifying an obstructed closure within an aperture, such identification resulting in the initiation of corrective action. Among the possible inputs from a contact-based system are motor shaft rotation rate or frequency, motor current, closure position, and duration of closure movement. Closure position in this context means the relative position of the closure within the aperture as well as whether the closure has reached a "fully closed" position. Among the possible inputs from a non-contact system are the degree to which a received amount of energy varies from an expected amount (i.e. either exceeds an expected amount or falls short of an expected amount, depending on the embodiment) and a shift in the time taken for the emitted energy to return to a receiver for some percentage of the total received energy.

Preferably, the controller 202 is capable of providing an output, through appropriate interface circuitry, which results in the stoppage of a closure for a respective aperture when the controller 202 determines that an obstruction is present. The closure may be commanded to reverse its motion and move to the fully open position. In addition, the controller 202 may provide an output

indicative of threshold achievement for the purpose of initiating some form of aural or visual alarm.

These and other examples of the invention illustrated above are intended by way of example and the actual scope of the invention is to be limited solely by the scope and spirit of the following claims.

CLAIMS

1. An obstacle detection system for a motor-driven closure within an aperture, comprising:

an emitter for generating an energy field proximate said aperture;

a receiver for receiving at least a portion of said energy field and for providing an output characteristic of said received energy field;

at least one sensor disposed in conjunction with said motor-driven closure, said at least one sensor for providing an output characterizing the performance of said motor-driven closure;

a system controller for receiving said receiver output and said at least one sensor output and for generating a closure control output in response thereto.

2. The system of claim 1, wherein said energy field is selected from the group consisting of an IR energy field and an ultrasonic energy field.

3. The system of claim 1, further comprising a non-volatile memory element in association with said system controller.

4. The system of claim 1, wherein said system controller is further for comparing said receiver output to a threshold value in establishing a first obstruction indicator.

5. The system of claim 4, wherein said system controller is further for comparing said at least one sensor output to a respective threshold value in establishing a second obstruction indicator.

6. The system of claim 5, wherein said system controller is further for generating said closure control output in response to both of said first and second obstruction indicators.

7. The system of claim 5, wherein said system controller is further for generating said closure control output in response to one of said first and second obstruction indicators.

8. The system of claim 7, wherein said controller is adapted for adjusting said receiver output threshold value based upon said receiver output if said second obstruction indicator has a first value.

9. The system of claim 7, wherein said controller is adapted for adjusting said at least one respective sensor threshold value based upon said at least one sensor output if said first obstruction indicator has a first value.

10. The system of claim 1, wherein said controller is adapted for adjusting a basis upon which said controller generates said closure control output if said receiver output is within a first range of values and said at least one sensor output is within a second range of values.

11. The system of claim 1, wherein said at least one sensor comprises a sensor for detecting the absolute position of said closure within said aperture, said sensor selected from the group consisting of a mechanical sensor and an optical sensor.

12. The system of claim 1, wherein said at least one sensor comprises a sensor for detecting the relative position of said closure within said aperture, said relative position being reflective of an offset from an initial position of said closure within said aperture, said sensor selected from the group consisting of a mechanical sensor and an optical sensor.

13. The system of claim 1, wherein said at least one sensor comprises a ripple count circuit in association with a motor driving said motor-driven closure within said aperture.

14. The system of claim 1, wherein said at least one sensor further comprises a current sensor for detecting the current drawn by a motor driving said motor-driven closure within said aperture.

15. The system of claim 1, further comprising a source for providing a timing signal to said system controller.

16. The system of claim 1, wherein said closure is selected from the group consisting of a vehicle window, a vehicle sunroof, a vehicle hatch, and a vehicle sliding door.

17. The system of claim 1, wherein said closure control output is a command to open said closure within said aperture.

18. The system of claim 1, wherein

said system controller is adapted to refer to only said receiver output in generating said closure control output

when a leading edge of said closure is within a first region of said aperture, and

said system controller is adapted to refer to both said receiver output and said at least one sensor output in generating said closure control output when said leading edge of said closure is within a second region of said aperture.

19. The system of claim 1, wherein said at least one sensor output is reflective of a variable selected from the group consisting of a motor shaft rotation rate, a motor drive current, a rate of change of a motor shaft rotation rate, a rate of movement of said closure within said aperture, an absolute position of a leading edge of said closure within said aperture, and a relative position of said leading edge of said closure within said aperture.

20. A method for monitoring a motor-driven closure within an aperture for the presence of an obstacle, comprising:

commanding said closure to move towards a closed position within said aperture;

monitoring a closure characteristic associated with said closure with a first sensor system;

monitoring an airspace characteristic associated with an airspace adjacent said aperture with a second sensor system; and

selectively identifying the presence of an obstacle by a controller based upon one or both of said closure and airspace characteristics, said controller associated with each of said first and second sensor systems.

21. The method of claim 20, wherein said monitoring of said closure characteristic further comprises monitoring a closure characteristic selected from the group consisting of closure rate of travel, rate of change of closure rate of travel, closure absolute position within said aperture, closure relative position within said aperture, closure motor drive current, closure motor ripple count, and closure motor drive shaft rotation rate.

22. The method of claim 20, wherein said monitoring of said airspace characteristic further comprises monitoring an airspace characteristic selected from the group consisting of a level of energy transmitted by an emitter then reflected to a receiver from the environment of said aperture, a level of energy transmitted by an emitter then absorbed by the environment of said aperture rather than reflected to a receiver, and a level of energy transmitted by an emitter and received by a receiver without attenuation in the environment of said aperture.

23. The method of claim 20, furthering comprising establishing the absolute position of said closure relative to said aperture.

24. The method of claim 23, wherein said selectively identifying comprises referencing said closure characteristic only if said established absolute position is within a first range of values and referencing said closure and airspace characteristics only if said established absolute position is within a second range of values.

25. The method of claim 20, wherein said selectively identifying the presence of an obstacle comprises comparing one or both of said closure and airspace characteristics with a respective reference value associated with said controller.

26. The method of claim 25, further comprising:

selectively adjusting said first sensor system by said controller in response to said comparing at least said airspace characteristics with said respective reference value.

27. The method of claim 25, further comprising:

selectively adjusting said second sensor system by said controller in response to said comparing at least said closure characteristics with said respective reference value.

28. The method of claim 20, wherein said monitoring an airspace characteristic comprises monitoring said airspace characteristic with a second sensor system selected from the group consisting of an IR emitting and detecting system and an ultrasonic emitting and detecting system.

29. An obstruction detection system for use with a power-driven panel in a motor vehicle, comprising:

a non-contact obstacle detection system disposed for monitoring the immediate environment of the panel;

a contact-based obstacle detection system disposed for monitoring the performance of the panel as it is moved towards a closed position; and

a controller in communication with said non-contact obstacle detection system and said contact-based obstacle detection system for selectively utilizing inputs from said non-contact and contact-based obstacle detection systems in identifying the presence of an obstacle in the panel travel path.

30. The system of claim 29 wherein said non-contact system comprises an IR emitter and receiver system adapted to detect a decrease in reflected IR energy when an obstacle is present within the panel travel path.

31. The system of claim 29 wherein said non-contact system comprises an IR emitter and receiver system adapted to detect an increase in reflected IR energy when an obstacle is present within the panel travel path.

32. The system of claim 29 wherein said non-contact system comprises an IR emitter and receiver system adapted to detect an decrease in received IR energy as a result of an obstacle blocking a portion of IR energy emitted by said emitter.

33. The system of claim 29 wherein said controller is adapted to identify the location of the panel based upon input from at least one of said non-contact and contact-based detection system and to utilize said inputs from said non-contact obstacle detection system when said panel is in a first range of locations and to utilize said inputs from said non-contact and contact-based obstacle detection systems when said panel is in a second range of locations.

34. The system of claim 29, wherein said contact-based system is selected from the group consisting of a panel motor ripple count circuit, a panel motor drive shaft rotation rate sensor, at least one sensor disposed adjacent said panel for detecting panel movement, and a panel motor drive current sensor.

35. The system of claim 29, wherein said panel is selected from the group consisting of a vehicle window, a vehicle sunroof, a vehicle hatch, and a vehicle sliding door.

36. The system of claim 29, wherein said controller is adapted for adjusting characteristics of said non-contact system based upon said input from said contact-based system.

37. The system of claim 29, wherein said controller is adapted for adjusting characteristics of said contact-based system based upon said input from said non-contact system.

38. The system of claim 29, wherein said non-contact system comprises an ultrasonic emitter and receiver system adapted to detect a difference between a predetermined range of times and the time for the transmission and receipt of a quantum of ultrasonic energy.

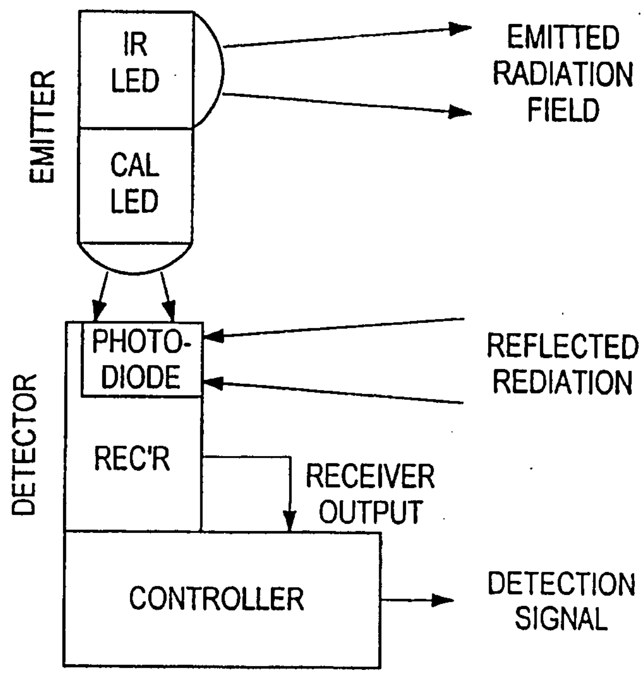



*FIG. 1*

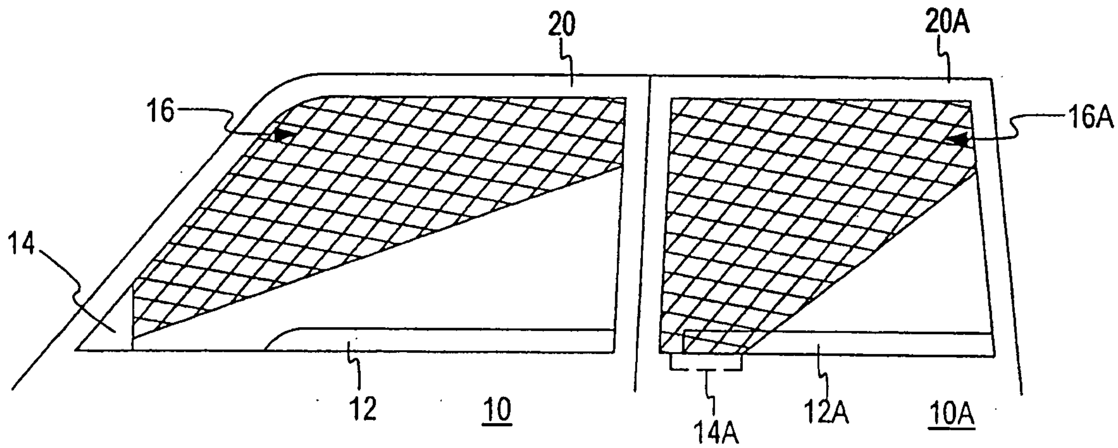



*FIG. 2A*

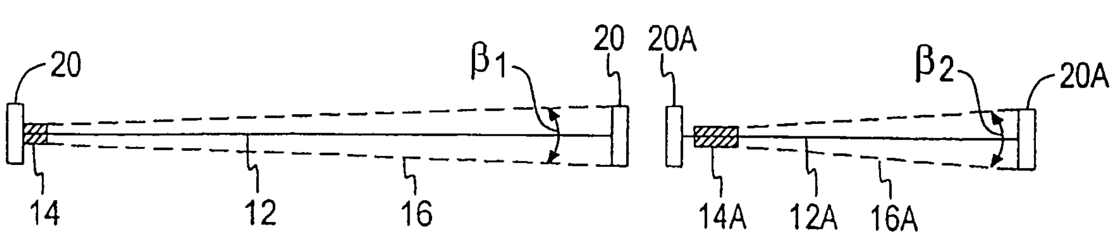



*FIG. 3*

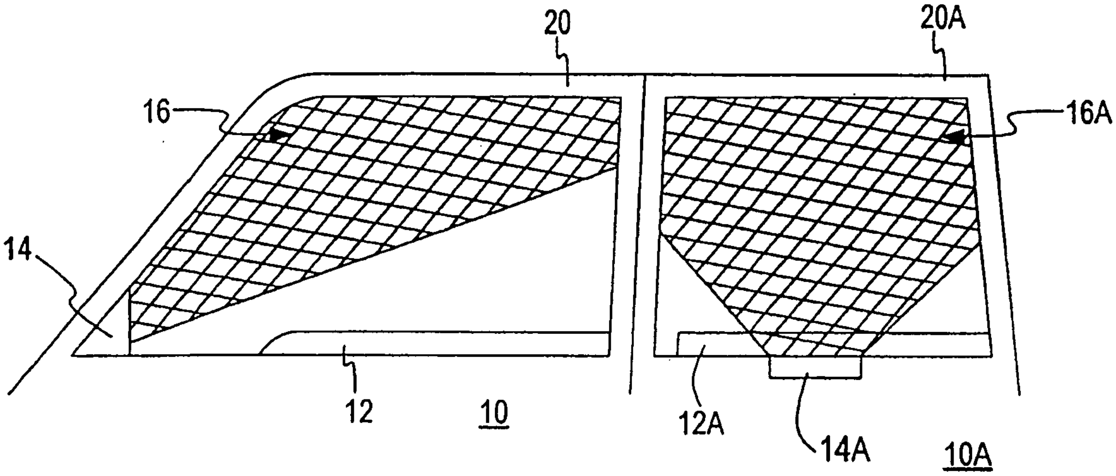

20
20A
16
16A
14
12
10
12A
14A
10A

FIG. 2B

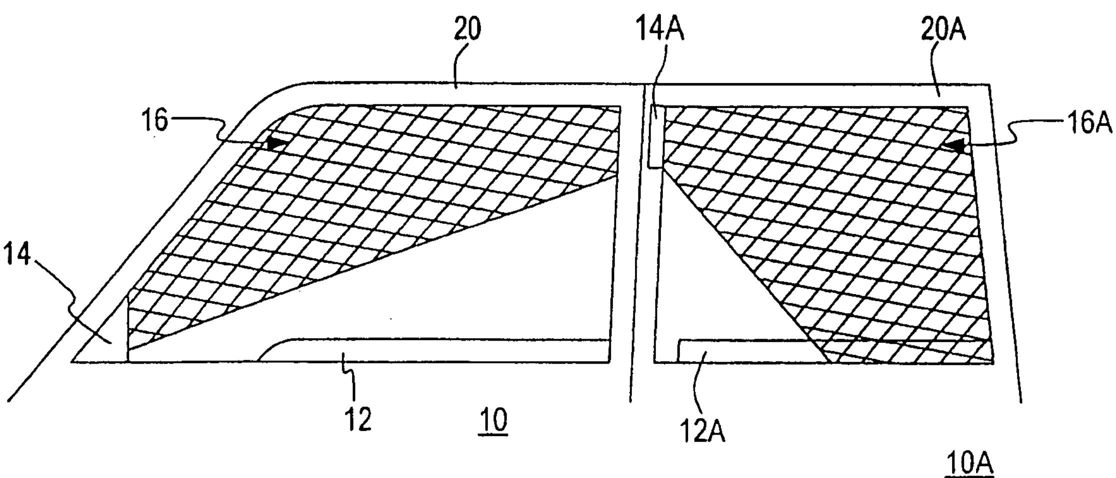

20
14A
20A
16
16A
14
12
10
12A
10A

FIG. 2C

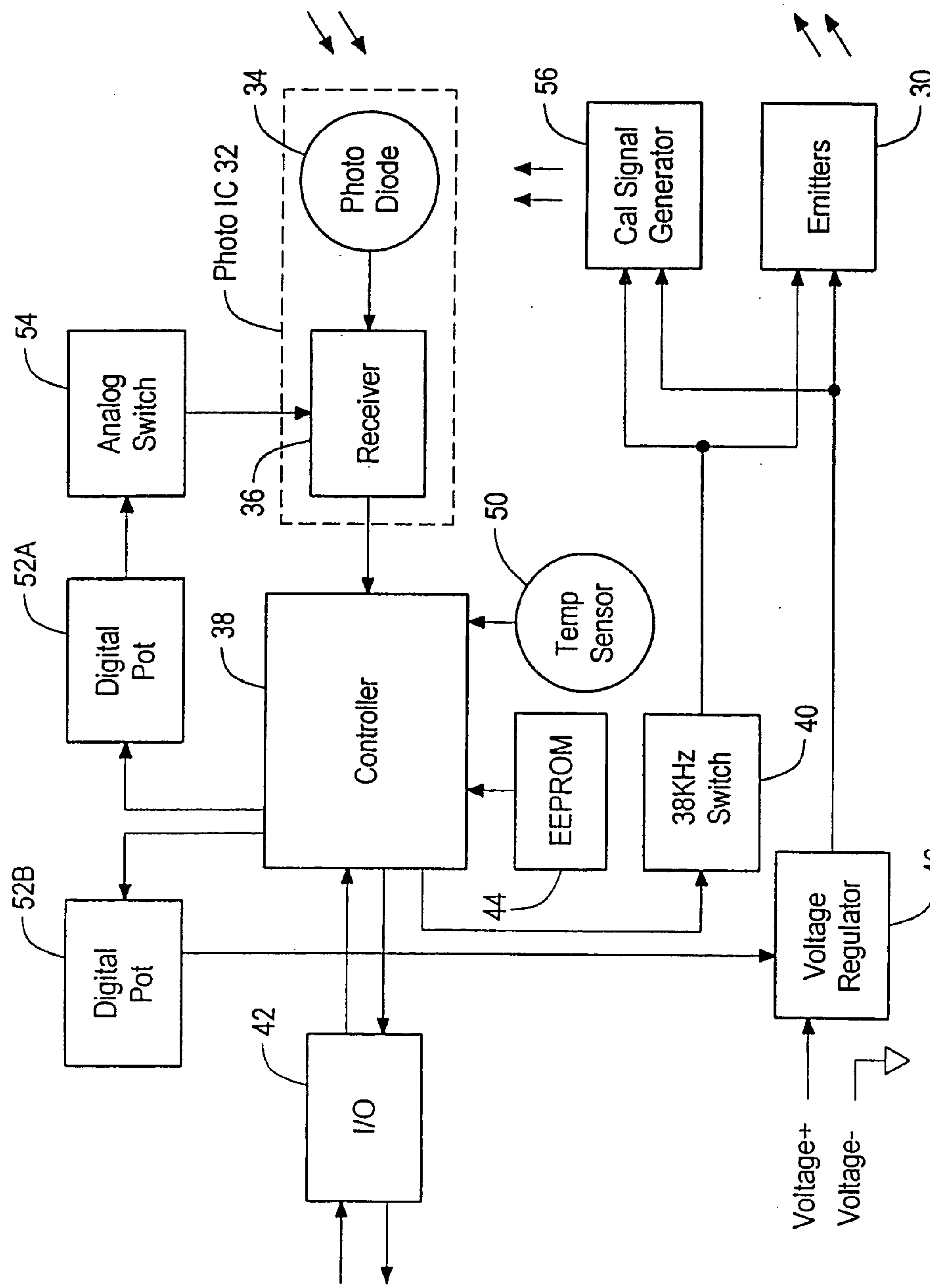


Photo Diode
34
Photo IC 32
Receiver
36
Analog Switch
54
Digital Pot
52A
Digital Pot
52B
Controller
38
Temp Sensor
50
EEPROM
44
38KHz Switch
40
Cal Signal Generator
56
Emitters
30
Voltage Regulator
46
I/O
42
Voltage+
Voltage-

*FIG. 4*

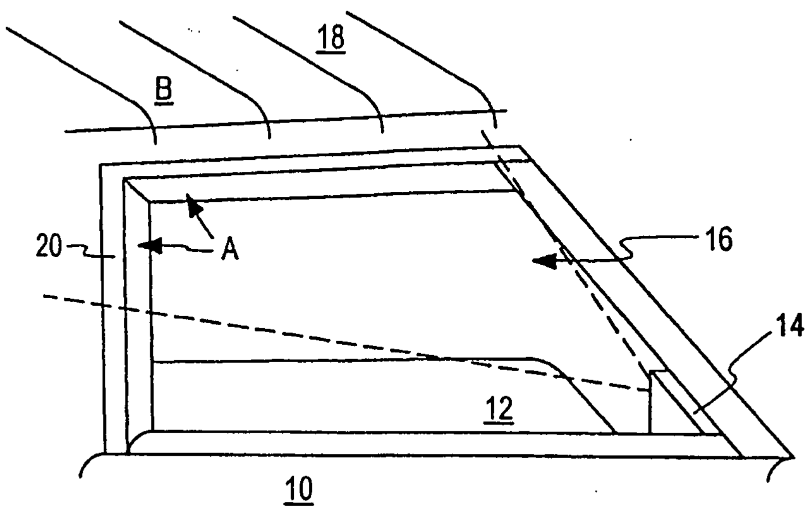



FIG. 5

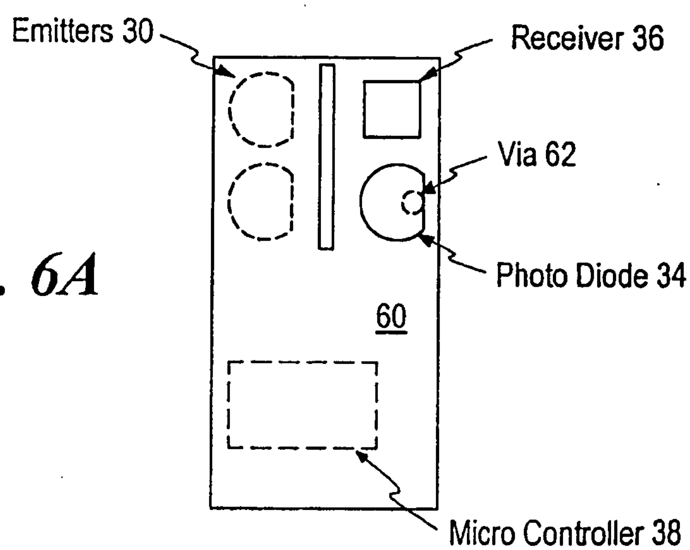



FIG. 6A

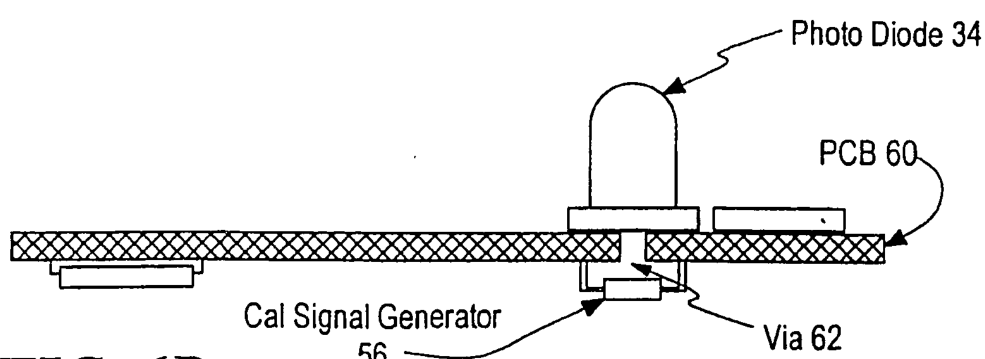



FIG. 6B

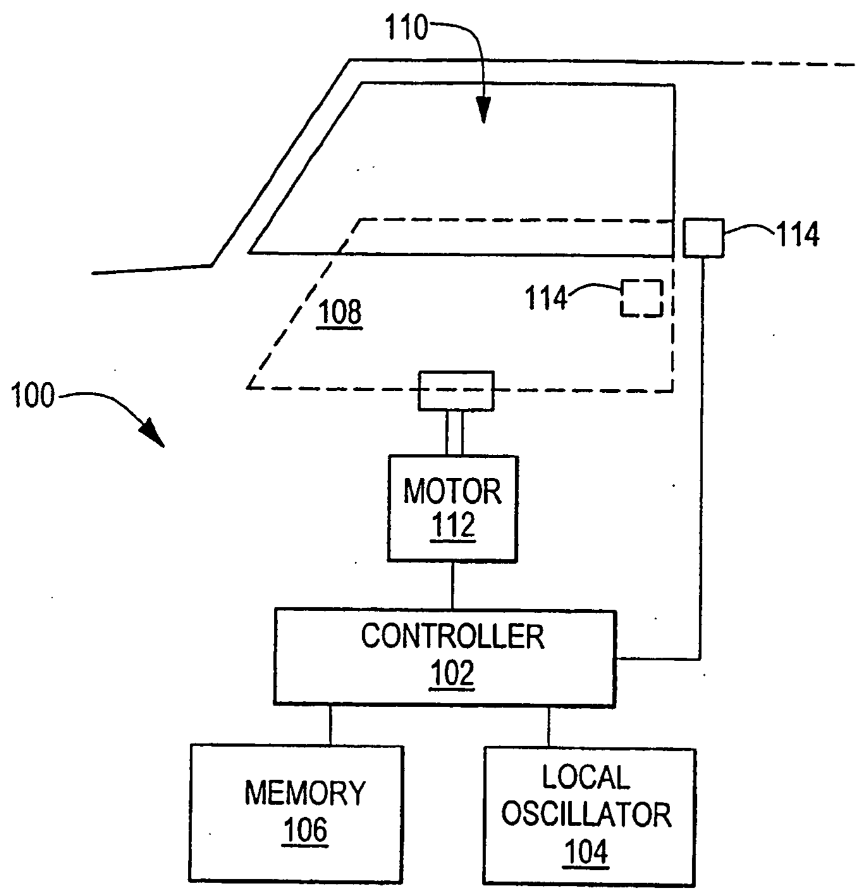

110
114
114
108
100
MOTOR
112
CONTROLLER
102
MEMORY
106
LOCAL
OSCILLATOR
104

FIG. 7

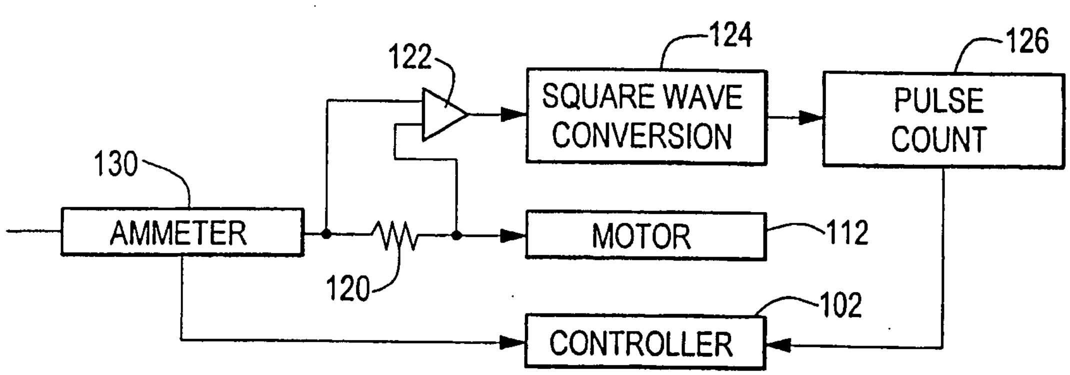

124
126
122
SQUARE WAVE
CONVERSION
PULSE
COUNT
130
AMMETER
MOTOR
112
120
102
CONTROLLER

FIG. 8

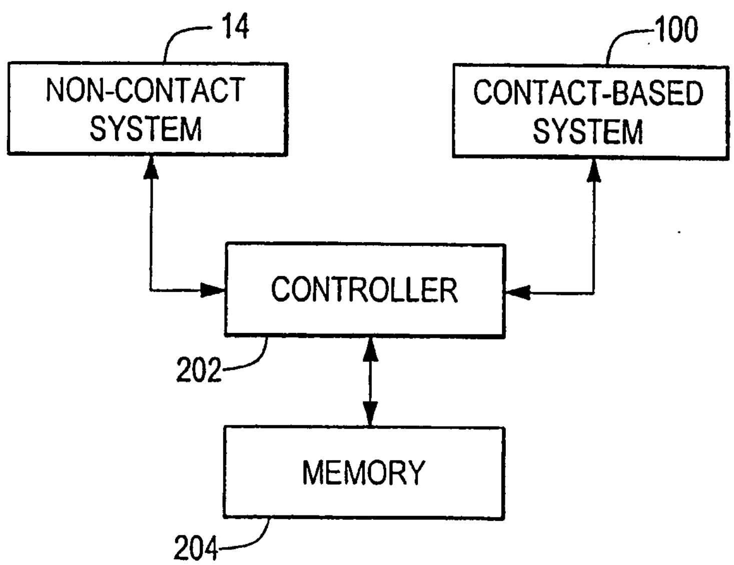

14
NON-CONTACT SYSTEM
100
CONTACT-BASED SYSTEM
CONTROLLER
202
MEMORY
204

*FIG. 9*

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/21510

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :E05F 15/20; H02P 1/22
US CL :49/25, 26, 27, 28, 31, 506; 318/480, 445, 460
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 49/25, 26, 27, 28, 31, 506; 318/480, 445, 460

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 5,955,854 A (ZHANG et al.) 21 September 1999, whole document. | 1-38 |
| Y, P | US 5,983,567 A (MITSUDA) 16 November 1999, whole document. | 1-38 |
| Y | US 5,969,637 A (DOPPELT et al.) 19 October 1999, whole document. | 3 |
| A | US 4,351,016 A (FELBINGER) 21 September 1982, whole document. | 1-38 |
| A | US 5,410,227 A (TOYOZUMI et al.) 25 April 1995, whole document. | 1-38 |
| A | US 4,410,843 A (SAUER et al.) 18 October 1983, whole document. | 1-38 |

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 18 OCTOBER 2000 | 15 DEC 2000 |

| Name and mailing address of the ISA/US | Authorized officer |
|---|---|
| Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231 | GREGORY J. STRIMBU Diane Smith |
| Facsimile No. (703) 305-3230 | Telephone No. (703) 305-3979 |

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/21510

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 4,458,446 (MOCHIDA et al.) 10 July 1984, whole document. | 1-38 |
| A | DE 4,030,607 A (WURZLE et al.) 16 April 1992, whole document. | 1-38 |
| A | WO 94/08120 A (LU et al.) 14 April 1994, whole document. | 1-38 |